Claims

[c1] 1. A method of multi-slice fast spin echo image acquisition with black-blood contrast comprising:

applying a non-selective inversion pulse;

applying a re-inversion pulse that is slice-selective over a region encompassing a plurality of slice selections;

timing execution of a series of RF excitation pulses with fast spin echo readout such that signal from blood is near a null point; and

acquiring data for the plurality of slice selections.

[c2] 2. The method of claim 1 wherein the plurality of slice selections include all slice selections in a slab to be imaged.

[c3] 3. The method of claim 1 wherein the images are acquired over more than a single breath-hold.

[c4] 4. The method of claim 1 wherein the re-inversion pulse is applied over a region having all slice selections in a slab and data are acquired for all slice selections in the slab using a single re-inversion pulse.

[c5] 5. The method of claim 1 further comprising creating the inversion pulse with slice thickness given by:

slice thickness = $(Z_1 - Z_n) + 4 * \text{opslthick}$,

where Z_1 and Z_n represents spatial locations of first and last slices selected for imaging, and opslthick represents a desired imaging slice thickness.

[c6] 6. The method of claim 5 further comprising creating the re-inversion pulse with a center centered about a midpoint between Z_1 and Z_n.

[c7] 7. The method of claim 1 wherein the timing step includes selecting an inversion time TI such that the null point of the blood occurs near a center of the multi-slice acquisition.

[c8] 8. The method of claim 1 further comprising modifying a flip angle of RF excitation pulses executed before and after an occurrence of the null point of the blood to improve blood suppression.

[c9] 9. The method of claim 8 further comprising modifying the flip of RF excitation pulses occurring before the null point to slightly less than 90 ° and those occurring after the null point to slightly more than 90 ° .

[c10] 10. A computer program for multi-slice coverage in a single acquisition with black-blood T_2 -weighted image contrast, the computer program having a set of instructions that when executed by a computer cause the computer to:
generate and cause application of a non-selective inversion RF pulse to a slab of slices each having a predefined thickness;
generate and cause application of a slice-selective re-inversion RF pulse having a slice thickness greater than the predefined thickness of a single slice;
apply an inversion time so that a null point of blood within the slab occurs in a middle of an acquisition segment;
apply a series of RF excitation pulses; and
acquire MR data for each slice in the slab.

[c11] 11. The computer program of claim 10 wherein the slice thickness of the re-inversion pulse is selected greater than the slab of slices to allow for cardiac motion between the application of the slice-selective re-inversion RF pulse, and the acquisition of MR data.

[c12] 12. The computer program of claim 10 wherein the RF excitation pulses have a flip angle greater than 90 ° for segments after the null point and less than 90 ° for segments before the null point.

[c13] 13. The computer program of claim 10 wherein the sequence is applicable over one or more R-R intervals.

[c14] 14. The computer program of claim 10 wherein the MR data is acquired during mid-diastole of an R-R interval.

[c15] 15. An MR apparatus to produce consistent contrast in FSE image acquisition comprising:
a magnetic resonance imaging (MRI) system having a plurality of gradient coils positioned about a bore of a magnet to impress a polarizing magnetic field and an RF transceiver system and an RF switch controlled by a pulse module to transmit RF

signals to an RF coil assembly to acquire MR images; and

a computer programmed to apply a pulse sequence having:

a non-selective inversion pulse to invert spins in a longitudinal direction across an entire slab of slices;

a slice-selective re-inversion pulse having an implied width at least as large as that of the non-selective inversion pulse; and

a series of excitation pulses having fast spin echo readout spaced apart from the slice-selective re-inversion pulse by an inversion time to acquire data for each slice in the slab.

[c16] 16. The MR apparatus of claim 15 wherein the slice-selective re-inversion pulse of the pulse sequence is further defined as having a width greater than that of the non-selective inversion pulse to extend on either side of the non-selective inversion pulse.

[c17] 17. The MR apparatus of claim 16 wherein the slice-selective re-inversion pulse extends approximately twice the nominal slice thickness on either side of the non-selective inversion pulse.

[c18] 18. The MR apparatus of claim 15 wherein the inversion time of the pulse sequence is selected such that blood signal is close to a null point.

[c19] 19. The MR apparatus of claim 18 wherein the series of excitation pulses have therein excitation pulses with differing flip angles.

[c20] 20. The MR apparatus of claim 19 wherein excitation pulses occurring near a mid-point of the series have a flip angle near 90 ° and excitation pulses occurring before a mid-point have a flip angle less than 90 ° and excitation pulses occurring after the mid-point have a flip angle more than 90 ° .

[c21] 21. A pulse sequence for use in multi-slice MR data acquisition comprising:

a non-selective inversion pulse applicable to a slab of slices;

a slice-selective re-inversion pulse applicable to at least a number of slices in the slab of slices; and

a series of fast spin echo readout excitation pulses applicable to the at least a number of slices in the slab of slices after an inversion time.

[c22] 22. The pulse sequence of claim 21 wherein the inversion time is selected to allow signal from blood in a mid-point of the at least a number of slices to approach a null point.

[c23] 23. The pulse sequence of claim 21 wherein the at least a number of slices includes all slices in the slab of slices.

[c24] 24. The pulse sequence of claim 21 wherein the at least a number of slices includes fewer slices than those in the slab of slices but more than one.

[c25] 25. The pulse sequence of claim 21 wherein the at least a number of slices includes more slices than those in the slab of slices.

[c26] 26. The pulse sequence of claim 21 wherein the non-selective inversion pulse has a thickness given by:
slice thickness = $(Z_1 - Z_n) + 4 * opslthick$,
where Z_1 and Z_n represents spatial locations of first and last slices selected for imaging, and opslthick represents a desired imaging slice thickness.

[c27] 27. The pulse sequence of claim 26 wherein the slice-selective re-inversion pulse has a center centered about a mid-point between Z_1 and Z_n.

[c28] 28. The pulse sequence of claim 21 wherein the series of fast spin echo readout excitation pulses have varying flip angles.

[c29] 29. The pulse sequence of claim 28 wherein excitation pulses that occur before a mid-point of the series have a flip angle of less than 90 °, those near the mid-point have a flip angle near or at 90 °, and those that occur after the mid-point have a flip angle greater than 90 °.